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ABSTRACT

This seventh in a series of ten modules for a course titled Welding Inspection describes how to determine what inspection is required for a given weld, when the inspection should be performed, and what acceptance standards apply. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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NUCLEAR TECHNOLOGY

COURSE 28 WELDING INSPECTION

MODULE 28-7 Acceptance Inspection

CE 024 267

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 28: WELDING INSPECTION

Module 28-1	Welding Fundamentals and Processes
Module 28-2	Shielded Metal Arc and Oxyacetylene Welding
Module 28-3	Tungsten Inert Gas (TIG), Metal Inert Gas (MIG) and Submerged Arc Welding
Module 28-4	Weld Joint Verification
Module 28-5	Qualifications
Module 28-6	Process Controls
Module 28-7	Acceptance Inspection
Module 28-8	Filler Metal Control
Module 28-9	Weld Repair Control
Module 28-10	Records

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This module was prepared for General Physics Corporation by John Espy, General Physics Corporation, and Ben Selleck, Ben-Sel Associates

GENERAL PHYSICS CORPORATION

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INTRODUCTION

Prior modules of this course have focused on all the controls aimed toward successfully making an acceptable weld. This module describes the inspections which determine if the completed weld is acceptable. Such inspections, of necessity, must be nondestructive in nature.

The techniques for performing nondestructive examinations are described by other courses of the Nuclear Technology Curriculum. Therefore, this module does not describe examination techniques. Instead, it describes how to determine what inspection is required for a given weld, when the inspection should be performed, and what acceptance standards apply. In this regard, the codes which govern acceptance of welds are described.

The content of this module pertains mostly to the acceptance inspection of welds as initially made during component manufacture and installation of such components at the nuclear power plant site. Inspection applied during the some 40 years of plant operation are also described. However, the inspections associated with weld repair are reserved for Module 28-9 of this course.

MODULE PREREQUISITES

All preceding modules of Course 28 shall be completed before proceeding to this module.

OBJECTIVES

Upon completion of this module, the student/trainee shall be able to:

1. Correlate given weld defects with the best method of nondestructive examination for detecting such defects.
2. Describe the general sequence of events whith result in identification of specific acceptance inspections for specific welds when the ASME Boiler and Pressure Vessel Code applies to manufacture or installation of components. Include the role of component classification and weld categorization.
3. Describe how either the Structural Welding Code, AWS D1.1, or the Reinforcing Steel Welding Code, D12.1, becomes applicable to nuclear power plant welding and name the types of welding governed by each of these codes.
4. Name the nondestructive examination method typically required by the ASME Boiler and Pressure Vessel Code for pressure boundary welds, filler welds, structural welds, and tube-to-tubesheet welds.
5. Relate the use of sequential processing instructions to the application of acceptance inspection instructions.
6. Name three conditions which dictate the point in time for performance of acceptance inspections.
7. Given descriptions or sketches of inspection results, determine the types of defects represented and compare the results with given acceptance standards to determine acceptability of the weld.

NOTES TO INSTRUCTOR / STUDENT

The Exercises and Procedures suggested by this module involve student/trainee research of codes applicable to welding. The availability of these codes in a reference library should be determined.

In the event the necessary codes are unavailable, activities should be developed which require students/trainees to apply acceptance inspection criteria. For such activities, descriptions of weld classifications and acceptance inspection requirements and acceptance standards for each classification would be needed. Such descriptions could be prepared from the information given by this module as supplemented from experience.

ACCEPTANCE INSPECTION METHODS AND CAPABILITIES

All inspection methods used to determine acceptability of product welds are nondestructive in nature. These inspections are typically categorized as visual inspection and nondestructive examinations (NDE). NDE methods used most frequently are radiography, liquid penetrant, magnetic particle, and ultrasonic testing. Other NDE methods used in unique applications are eddy current testing and gas and bubble testing. Course 26, NDE Techniques I, and Course 32, NDE Techniques II, describe the specific techniques associated with each NDE method.

The function of the weld and the capabilities of the acceptance inspection method determine the specific acceptance inspections required for a given weld. As described later in this module, governing codes and design documents prescribe the specific acceptance inspection and acceptance standards. At this point, the capabilities of each method are reviewed.

Visual inspection, liquid penetrant testing, and, for practical purposes, magnetic particle testing are capable of detecting weld defects on or open to the surface of a weld. While magnetic particle testing has the capability of detecting defects slightly below the surface, it is considered a surface inspection for practical purposes. Radiography, ultrasonic, and eddy current testing are capable of detecting subsurface defects. Radiography and eddy current will also detect certain surface defects. Eddy current testing has depth limitations such that it is typically employed for special testing of relatively thin-walled members. Other than for tubing, eddy current testing finds little use in nuclear power plant applications. Gas and bubble tests are used to determine integrity of certain

welds in storage tanks. Within these general capabilities, the specific capabilities of each method, as applied to welds, are given in Table 28-7-1.

Table 28-7-1
NDE Capabilities

Type of Defect	Detectable By						
	Visual	Liquid Penetrant	Magnetic Particle	Radiography	Ultrasonic	Eddy Current (4)	Gas and Bubble
Arc Strikes	x						
Excessive reimforcement	x			x			
Excessive concavity or convexity	x			x			
Undercut	x	(1)	(1)	x			
Bead Overlap (rollover)	x	x	x	x			
Pitting	x	x	x	x		x	
Spatter	x			x			
Incomplete fusion				x	x	x	
Cracks		(2)	(2)	x	x	x	x
Porosity		(2)	(2)	x		x	
Inclusions		(2)	(2)	x	(3)	x	
Burn through	x			x	x	x	
Underbead cracking				x	x	x	

Notes:

(1) Undercut provides a poor surface for liquid penetrant and magnetic particle testing. While it is detectable by these methods, visual inspection and radiography are

relied upon to detect undercut. Undercut is repaired prior to performing any required liquid penetrant or magnetic particle testing.

(2) Cracks, porosity, and inclusion are detectable by liquid penetrant and magnetic particle testing when these defects are open to the surface.

(3) Large inclusions are detectable by ultrasonic testing.

(4) Eddy current testing is applicable to thin wall members only.

Table 28-7-1 indicates that defects detactable by visual inspection are also detectable by certain NDE methods. While this is factual, the visual inspection is expected to be accomplished and result in correction of such defects prior to performing NDE. However, if NDE detects visually discernible defects, such NDE would report them for correction.

Reliance is placed on visual inspection for the visually discernible defects because it is the better inspection method and because such defects can mask other defects detectable by NDE. For example visually discernible defects affect NDE as follows:

- excessive reinforcement causes dark areas on radiographs which can mask internal defects.
- excessive concavity on convexity causes lighter or darker areas respectively on radiographs but their size is not easily measured by radiographic techniques.
- undercut causes dark areas on radiographs which can mask internal defects.
- bead overlap causes linear magnetic particle and liquid penetrant indications which appear to be cracks. Radiography may or may not detect overlap dependent on the angle of radiation beam.
- pitting always gives magnetic particle and liquid penetrant indications; the much quicker visual

inspection is preferred. Pitting appears as dark rounded indications on radiographs which may mask internal defects or be confused with porosity or inclusions.

- spatter gives light indications on radiographs which may mask or be confused with internal defects.
- burnthrough gives irregular dark and light areas on radiographs and irregular responses to and eddy current examination which may mask internal defects. It is noted, however, that for welds whose inside surfaces are not visible, radiography is relied upon for detection of burnthrough.

CODES AND SPECIFICATIONS

For either shop or field welds, the QA/QC Technician is concerned with what NDE method is required and at what stage of welding should it be applied. Engineering activities normally have lead responsibility for specifying the NDE method and its application. In doing so, engineers must correctly apply the provisions of governing codes and specifications. The QA activity may have the responsibility to review or audit the results. The QC activity typically has lead responsibility for performing NDE.

The three principle codes are ASME Boiler and Pressure Vessel Code, AWS Structural Welding Code, and AWS Reinforcing Steel Welding Code. The application of NDE requirements of these codes is described below.

ASME Boiler and Pressure Vessel Code

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code consists of eleven sections. Sections III and XI specify acceptance inspections and inservice inspections of welds respectively.

Section III of the code governs design, fabrication and testing of mechanical components for nuclear power plants. Section III applies to reactor vessels, other pressure vessels, pumps, valves, piping and storage tanks which comprise the nuclear power plant mechanical systems. The design agency for the power plant classifies the components consistent with the rules of the Boiler and Pressure Vessel Code. For each classification, there is a corresponding subsection of Section III which delineates design, fabrication, and testing requirements. Table 28-7-2 illustrates this correspondence.

Table 28-7-2

ASME Component Classifications

Component Class	Corresponding Subsection of Code
All	Section III, Subsection NA, Nuclear Power Plant components; General Requirements
Class 1 vessels, pumps, valves, piping, storage tanks	Section III, Subsection NB, Class 1 Components
Class 2 vessels, pumps, valves, piping, storage tanks	Section III, Subsection NC, Class 2 Components
Class 3 vessels, pumps, valves, piping, storage tanks	Section III, Subsection ND, Class 3 Components
Class MC, metal containment vessels	Section III, Subsection NE, Class MC Components
Class CS, core supports and component supports	Section III, Subsection NF, component supports Section III, Subsection NG, core supports

These component classes may be briefly defined in the following manner:

Class 1: These consist of vessels, pumps, valves, piping, and storage tanks which are part of the Reactor Coolant System (RCS) (for example, for a pressurized water reactor, PWR).

Class 2: These consist of all vessels pumps, valves, piping, and storage tanks which are part of the Emergency Core Cooling System (ECCS) Main Steam System (MS) and Feedwater System (FW).

Class 3: These consist of all vessels, pumps, valves, piping, and storage tanks for all other cooling water systems essential to safety of the plant (for example, the essential cooling water system and component cooling water systems would be considered here).

Class MC: Refers to the metal containment liner for the reactor containment building. This liner is supported by the reinforced concrete containment structure.

Class CS: This refers to reinforced concrete pressure vessels for a gas cooled reactor.
It also refers to the core supports and those structural members inside the reactor vessel.
It also refers to all of the component supports for those components which perform a safety function.

Section III requires the design agency to prepare a design specification for each component and for the system in which the component will be installed. Such design specifications give sufficient information to allow determination of the acceptance inspections required by the code.

As a minimum, the design specification must identify component name, classification, and type of weld joint to permit determination of acceptance inspection requirements for a given weld.

When the component name and classification is known, the applicable subsection of Section III is easily determined as illustrated previously in Table 28-7-2. Each subsection of Section III is arranged by Articles to have the same format as illustrated in Table 28-7-3.

Table 28-7-3

Subsection Format

Article Number	Title
1000	Introduction or Scope
2000	Material
3000	Design
4000	Fabrication and Installation
5000	Examination
6000	Testing
7000	Protection Against Overpressure
8000	Name plates, Stamping, and Reports

As indicated in Table 28-7-3, Article 3000 of any subsection governs the component design. In most subsections, Article 3000 requires a further classification of welds as category A, B, C or D. These categories are based on location, service, material and thickness of the weld. Rules governing categorization of welds are as follows; a typical application is illustrated in Figure 28-7-1.

- Category A - Category A welds are comprised of longitudinal weld joints within main shells, chambers, transitions in diameter and nozzles; any welded joint

within a sphere, formed or flat head, or side plates of a flat-sided vessel; and circumferential weld joint connecting hemispherical heads to other pressure retaining members.

- Category B - Category B welds are comprised of circumferential weld joints within main shells, chambers, nozzles, transitions in diameter and circumferential weld joints connecting heads other than hemispherical to other pressure retaining members.
- Category C - Category C welds are comprised of welded joints connecting flanges, tube sheets, or flat heads to other pressure retaining members and any weld joint connecting one side plate to another side plate of a flat sided vessel.
- Category D - Category D welds are comprised of welded joints connecting chambers, or nozzles to other pressure retaining members.

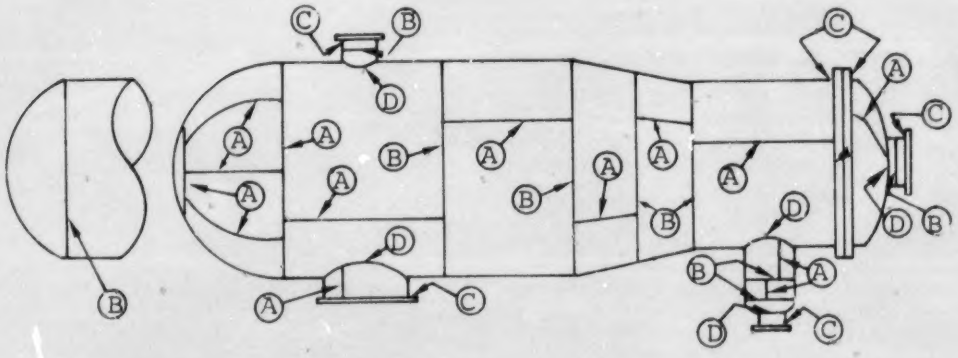


Figure 28-7-1 Typical Application of Categories A, B, C and D Welds

Article 4000 of the applicable subsection of Section III stipulates welding requirements applicable to the component manufacturer and the construction contractor at the

power plant site. These requirements govern weld joint preparation, fit-up, welding, and post weld heat treatment. Article 4000 contains requirements applicable to all weld categories and unique requirements applicable to specific weld categories.

Article 5000 of the applicable subsection of Section III stipulates the acceptance inspection requirement for all combinations of types of component and categories of weld within the component. The acceptance inspection are stipulated by listing the NDE methods to be employed, the point of manufacture or construction they are to be employed, and the acceptance standards for each method.

The above discussions indicate that a series of events occur in order to properly apply the acceptance inspection requirements of Section III of the Boiler and Pressure Vessel Code. This sequence is typically as follows:

- Classification of components - The design agency includes in the system design specification the classification of each component of the system. The component classification permits determination of the applicable subsection of Section III by the manufacturer and construction contractor.
- Categorization of welds - Component welds can be categorized once the component design drawings have been prepared. Installation welds can be categorized once the system design drawings have been prepared. These design drawings identify location of welds from which welds can be categorized in accordance with Article 3000 of the applicable subsection of Section 3. Categorization of welds is normally performed by the engineering activity of the manufacturer or construction contractor. The design agency may desire to approve such categorization.

- Development of Fabrication or Installation Instructions - These instructions identify the processing steps and sequences necessary to manufacture or install the component. The engineering activity of the manufacturer or construction contractor prepare such instructions to implement the requirements of the design specification and Article 4000 of the applicable subsection of Section III. These instructions are typically termed "job package" which consists of sequential manufacturing or installation steps (e.g. traveller process routing, or job order), detail drawings, and applicable procedures such as the welding procedure specification for the job.
- Development of Acceptance Inspection Instructions - Using the component classification, the weld category, and the fabrication or installation instructions, one can locate in Article 5000 the specific acceptance inspection requirements. For a given component classification and weld category, Article 5000 lists the specific nondestructive examinations required and any requirements pertaining to the point in time where such NDE must be applied. From the manufacturing or installation instructions, the sequence matching the time dependent requires of Article 5000 can be selected. This task is accomplished by either the engineering or the QA/QC activity of the manufacturer or construction contractor. Whichever activity has lead for this task, the other activity normally has a review and concurrence function. The end result is the addition of steps for performing required NDE at the proper sequence on the manufacturing or installation listing of sequential work steps for each job.

Section XI of the ASME Boiler and Pressure Vessel Code specifies "inservice inspection" requirements for welds, pumps, and valves for the operations phase of a nuclear power plant. With regard to welds, Section XI requires classification of pressure boundary welds as class 1, 2 or 3 dependent upon the service function of the weld and its ability to be isolated from the reactor vessel. Periodic examination of these welds is required on a frequency dependent on the classification.

AWS Structural Welding Code, D1.1

The American Welding Society's Structural Welding Code, D1.1, applies to the welding of steel structures other than those components governed by the Boiler and Pressure Vessel Code. In nuclear power plant applications, the AWS Structural Welding Code typically governs welding associated with steel erection and other building construction. While the Boiler and Pressure Vessel Code governs design of components including welding design criteria, the AWS Structural Welding Code gives design criteria for welded structures only. The Architect-Engineer must determine if the AWS Structural Welding Code is pertinent to the design and whether it will be employed. Therefore, this code is applicable only when specified by the Architect-Engineer of the nuclear power plant.

The Architect-Engineer, who is the utility company or their contractor, specifies via system or component design specifications those welding operations which must meet the AWS Structural Welding Code. Where specified, the engineering and QA/QC activities of the construction contractor develop "job packages" for welding which comply with the AWS Structural Welding Code. These job packages are similar to those prepared for welding operations to the Boiler and Pressure Vessel Code. An overview of the code and its significance

to engineering and QA/QC activities are given in Table 28-7-4. As indicated in the table, Section 6 of the code specifies visual inspection of welds and requires the Architect-Engineer to specify any NDE to be performed. Section 8 of the code specifies acceptance standards for welds.

AWS Reinforcing Steel Welding Code, D12.1

The American Welding Society's Reinforcing Steel Welding Code D12.1, gives requirements associated with welding of reinforcing steel in concrete structures. It is intended for use in conjunction with American Concrete Institute's Building Code Requirements for Reinforced Concrete, ACI-318. It is applicable to nuclear power plant construction only when specified by the Architect-Engineer.

Where the AWS Reinforcing Steel Welding Code is specified, the construction contractor's engineering and QA/QC activities developed "job packages" for welding of reinforcing steel which comply with the code. An overview of the code and its significance to engineering and QA/QC activities are given in Table 28-7-5. As indicated in the table, Section 7 of the code specifies visual inspection of welds and requires the Architect-Engineer to specify any NDE to be performed. Section 4 gives acceptance standards for completed welds.

Table 28-7-4

Overview of AWS Structural Welding Code

Section	Purpose	Application
1. General Provisions	Describes applicability of the code and gives general requirements which are applicable to any welding governed by the code	Architect-Engineer invokes the code consistent with its applicability; construction engineering develops welding procedures consistent with the general requirements.
2. Design of Welded Connections	Gives specific requirements governing the design of weld joints.	Construction engineering designs weld joints consistent with these specific requirements.
3. Workmanship	Gives specific requirements for the weld joint preparation, fit-up, distortion control, stress relief heat treatment, and cleaning associated with welding operations.	Construction engineering prepares welding procedures, installation drawings, and sequential listings of work steps consistent with these specific requirements.
4. Technique	Gives specific welding parameters for each welding process, including filler material, preheat and interpass temperatures shielding, positions and electrical characteristics. Also gives specific requirements pertaining to arc strikes and interpass cleaning.	Construction engineering prepares welding procedure specifications consistent with these requirements.
5. Qualification	Gives specific requirements for the qualification of welding procedures and welders.	Construction engineering establishes qualification testing of weld procedures and welders consistent with these requirements.
6. Inspection	Specifies visual inspection which are to be performed by the inspection agency designated by the project engineer. Requires the purchaser of construction work (i.e., the utility company) to specify any application of nondestructive examination (NDE). Gives requirements to be met by NDE procedures and for qualification of NDE personnel when NDE is specified.	The designated QA/QC activity performs visual inspection consistent with these requirements. When specified, the QA/QC activity prepares NDE procedures, qualifies NDE personnel, and performs NDE consistent with this section.

Table 28-7-4

Overview of AWS Structural Welding Code (Cont'd.)

7. Strengthening and Repairing Existing Structures	Gives requirements for the modification or repair by welding of existing structures	The construction or maintenance engineering activity develops modifications or repairs consistent with these requirements.
8. Design of New Buildings	Gives design criteria which must be considered with respect to welding associated with building construction. These criteria supplement sections 1 through 6 of the code. Gives acceptance standards for completed welds.	Either the design activity or the construction engineering activity design weld joints consistent with these requirements. Inspection of welds determines compliance with specified acceptance standards.
9. New Bridges	Not applicable to nuclear power plants.	Not applicable to nuclear power plants.
10. New Tubular Structures	Gives design critiera which must be considered with respect to welding associated with tubular structures. These criteria supplement section 1 through 6 of the code. Gives acceptance criteria for completed welds.	Either the design activity or the construction engineering activity design weld joints consistent with these requirements. Inspection of welds determines compliance with acceptance criteria.

Table 28-7-5

Overview of AWS Reinforcing Steel Welding Code

Section	Purpose	Application
1. General Provisions	Describes applicability of the code and gives general requirements which are applicable to any welding to the code.	Architect-Engineer invokes the code consistent with its applicability; construction engineering develops welding procedures consistent with the general requirements.
2. Permissible Stresses	States permissible stress limits for welded joints in reinforcing steel.	Construction engineering designs weld joints to meet these limits.
3. Structural Details	Gives details of weld joint type preparation, and fit-up.	Construction engineering prepares installation drawings and instructions consistent with these requirements.
4. Workmanship	Gives specific requirements for preparing weld end faces, fit-up, distortion control, and the acceptance standards for completed welds.	Construction engineering prepares installation drawings and instructions consistent with these requirements. Inspection determines compliance of completed welds with the acceptance standards.
5. Technique	Gives specific requirements for welding processes including preheat and interpass temperature, arc strikes tack welds, progression, filler material and shielding.	Construction engineering prepares welding procedures consistent with these requirements.

Table 28-7-5

Overview of AWS Reinforcing Steel Welding Code (Cont'd.)

6. Qualification	Gives specific requirements for the qualification of welding procedures and welders.	Construction engineering establishes qualification testing of procedures and welders consistent with these requirements.
7. Inspection	Specifies visual inspections which are to be performed by the inspection agency designated by the project engineer. Requires the purchaser of construction work to specify any application of NDE. Gives requirements to be met by NDE procedures and for qualification of NDE personnel when NDE is specified.	The designated QA/QC activity performs visual inspection consistent with these requirements. When specified, the QA/QC activity prepares NDE procedures, qualifies NDE personnel, and performs NDE consistent with this section.

APPLICATION OF ACCEPTANCE INSPECTIONS

The specific acceptance inspection method employed for a given weld is specified by the governing welding code and/or the design specification. Typical applications are described by this module; on-the-job QA/QC activities must refer to the applicable code and design specification to determine which acceptance inspection methods apply to a specific weld.

Examinations Required by ASME Boiler and Pressure Vessel Code

The ASME Boiler and Pressure Vessel Code bases acceptance of welds on specified nondestructive examination (NDE) methods. Section III of the code specifies the NDE require-

ments for manufacturing and construction. Section XI of the code specifies the NDE requirements for periodically inspecting welds during the lifetime of the plant.

As previously described by this module, NDE requirements for manufacturing and construction are found in Article 5000 of the subsection of Section III for the type and class of component associated with the welding operation. In general, Article 5000 of the various subsections specifies the time of examination, the NDE methods to be used, and the acceptance standards for each NDE method. Typical requirements for time of examination and method of NDE are as follows; the acceptance standards are described later in this module:

- time of examination - Time of examination refers to the point in the manufacturing or construction sequence at which the NDE must be performed. The code requirements are structured to ensure acceptance of welds at a point in time where later manufacturing or construction sequences would not adversely affect the integrity of the weld. Typical requirements are:
  - except for certain stipulated conditions, radiography, magnetic particle, or liquid penetrant are performed after post weld heat treatment.
  - all dissimilar metal welds are examined after post weld heat treatment.
  - magnetic particle or liquid penetrant examinations of weld surfaces which will be covered with weld metal cladding are performed prior to depositing the cladding.
- method of NDE - Specific NDE requirements are specified for each type and classification of component. Typical requirements are:
  - magnetic particle or liquid penetrant examination of weld end faces prior to welding of joints two inches or more in thickness.

- radiography of completed pressure boundary welds in vessels, pipe, pumps, valves, and certain welds in storage tanks. The category of weld typically determines if the entire weld or a portion of the weld is radiographed.
- ultrasonic examination of welds made by the electroslag welding process.
- magnetic particle or liquid penetrant examination of filter welds, structural attachment welds, seal welds, and certain welds in storage tanks.
- liquid penetrant examination of weld metal cladding, hard surfaces, and tube-to-tubesheet welds.
- visual examination of stud welds.
- gas and bubble leak tests of certain welds of atmospheric storage tanks.

The inservice inspections specified by Section XI of the code are ultrasonic, magnetic particle and liquid penetrant. Ultrasonic examination applies to all class 1 welds and many class 2 and 3 welds. The remainder are inspected by magnetic particle or liquid penetrant testing.

Examination Required by Structural Welding Code and Reinforcing Steel Welding Code

The AWS Structural Welding Code, D1.1, and Reinforcing Steel Welding Code, D12.1, specifically require visual inspection for the following:

- size, length, and location of welds
- no omission or addition of weld joints without engineering approval
- no welding defects in excess of acceptance standards

As previously described, the Architect-Engineer may specify NDE methods to be used. In general, the welds covered by AWS D1.1 and AWS D12.1 are such that either radiography

or magnetic particle examination or both would be the only NDE specified.

Significance of Application of "Magnetic Particle or Liquid Penetrant" Examination

Design specifications and the Boiler and Pressure Vessel Code specify NDE requirements by type and classification of weld joints. The base material type is normally not a direct consideration with respect to specifying the NDE method. For this reason, when weld surface inspection is required, the specification code typically specifies "magnetic particle or liquid penetrant" examination. In such cases, most companies employ the practice of applying magnetic particle examination when the weld metal is capable of being magnetized.

Carbon steels and low alloy steels are easily magnetized. Welds made of these materials are typically examined by magnetic particle as opposed to liquid penetrant examination. High alloy steels, e.g. stainless steels, have some magnetic properties but generally not of sufficient value to permit application of magnetic particle examination. Copper and aluminum alloys and most nickel alloys are non-magnetic. Therefore, for these alloys, liquid penetrant examination is employed as opposed to magnetic particle examination.

Magnetic particle and liquid penetrant examination have essentially equal capabilities. The preference for magnetic particle examination whenever the weld metal has ample magnetic properties is based on productivity. Magnetic particle examination is substantially faster than liquid penetrant examination.

ACCEPTANCE STANDARDS

Unless otherwise specified by the design specification, the applicable acceptance standards are those specified by the code which governs the welding. Sections of the three codes described by this module which specify acceptance standards have previously been listed. In all three codes, the acceptance standards are similar. The specific limits on defect sizes or number are the principle differences among the three codes. Therefore, the acceptance standards described in the following paragraph are representative of all three codes. For on-the-job work, the specific code applicable to the welding would be used to determine acceptance standards.

Radiographic Acceptance Standards

Welds examined by radiography are considered acceptable if the radiography indicates:

- no crack, underbead crack, or incomplete fusion - Such indications appear on the radiograph as dark lines which clearly defined edges.
- no elongated indications exceeding specified lengths - Such indications represent inclusion on burnthrough. Acceptable lengths of indications are specified for various ranges of weld metal thickness. High density inclusions such as tungsten and globules of weld metal resulting from burnthrough appear on the radiograph as light, elongated shapes with edges farily well defined. Low density inclusions such as slag and areas of burnthrough where metal has fallen away appear on the radiograph as dark, elongated shapes whose edges are normally ill defined. Burnthrough is distinguishable from inclusion because both dark and light areas appear on the radiograph.

- no rounded indications in excess of specified size limits or total numbers - Rounded indications represent porosity. They appear on the radiograph as dark, rounded shapes whose edges may not be sharply defined. Indications are considered rounded if their maximum length is three or less times their width.
- no groups of aligned indications have a total length over a specified limit - Aligned indications are those elongated and rounded indications which touch a hypothetical line between the center points of the two outermost indications, and which are not spaced more than a specified distance. The concern with indications which are acceptable except for their alignment is that they probably represent a crack which was only partially detected by the NDE.

Ultrasonic Acceptance Standards

Welds inspected by ultrasonic examination are acceptable except as follows:

- discontinuities interpreted as cracks, underbead cracks, or incomplete fusion are unacceptable - The inspector determines the type of discontinuity by investigating ultrasonically the shape of the discontinuity. Discontinuities having length but essentially no width are interpreted as cracks, underbead cracks, or incomplete fusion dependent on their location.
- discontinuities are unacceptable if they exceed specified amplitudes or lengths - The amplitude of the ultrasonic response from the discontinuity which is unacceptable is normally specified as any value greater than the reference level obtained from the calibration block. Such amplitude would indicate a discontinuity of larger size than the notch or

drilled hole in the calibration block. Unacceptable lengths are specified for various ranges of weld metal thickness.

Magnetic Particle Acceptance Standards

Welds inspected by magnetic particle examination are acceptable if there are:

- no cracks - Cracks appear as linear alignment of magnetic particles.
- no rounded indications exceeding specified limits of size, number, or alignment - Limits on number of rounded indications are normally specified in terms of number per six square inches of weld surface with such areas being the most unfavorable for weld acceptance. Limits on alignment of rounded indications are normally specified in terms of the number and their spacing, e.g., four or more spaced less than 1/16 inch between any two and in alignment.

Liquid Penetrant Acceptance Standards

Welds inspected by liquid penetrant examination are acceptable if there are:

- no cracks - Cracks appear as linear bleed out of the penetrant when developer is applied.
- no rounded indications exceed specified limits of size, number, or alignment - Such limits are normally specified in the same manner as for magnetic particle acceptance standards.

Gas and Bubble Leak Testing Acceptance Standards

Welds examined by gas and bubble leak testing are acceptable provided there is no leaking as evidenced by formation of bubbles or the breaking of a continuous film.

Visual Inspection Acceptance Standards

Visual inspection of welds employs measuring devices, mirrors, lights, and magnification as necessary to accomplish the inspection. Welds visually inspected are acceptable provided there are:

- no cracks which are visually discernable.
- no unfilled craters - Craters occur at welding stops. Craters are either filled or grounded flush with surrounding weld metal.
- no unacceptable weld profiles - This standard pertains to reinforcement, concavity, convexity, undercut, overlap, and throat thickness. Such conditions are illustrated in Figure 28-7-2 for reinforcing steel welding.

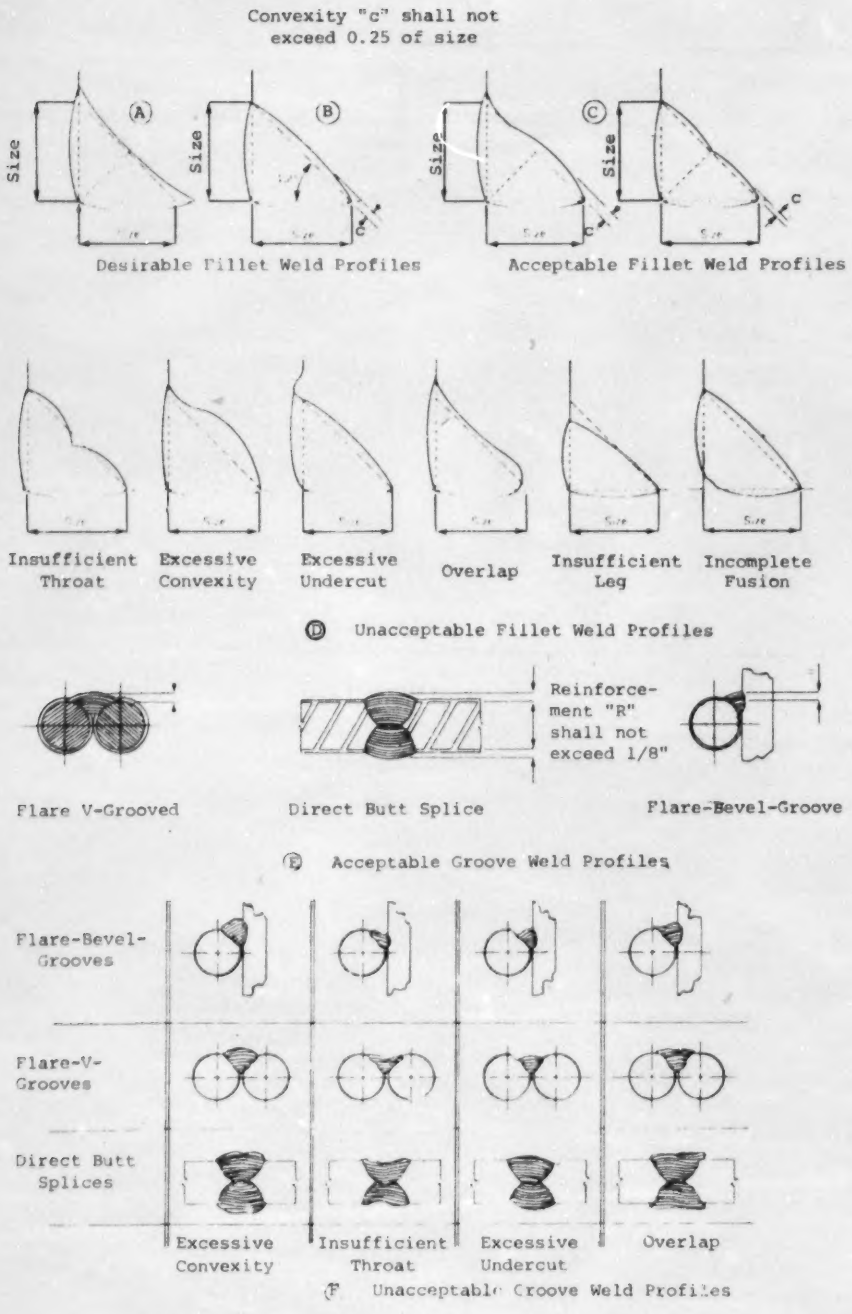


Figure 28-7-2 Weld Profile Standards for Reinforcing Steel Welding

EXERCISES

The following exercises serve to reinforce the concepts presented in this module. The first exercise should involve an assigned weld, wherein the review of the applicable code, acceptance inspection and standards may be carried out. The remaining exercises involve questions regarding the module material.

1. Using the Procedures specified for this module, review the applicable code and extract the weld acceptance inspection requirements and corresponding acceptance standards. Locate the applicable sections, subsections and articles of the code using the guidelines presented in this module.
2. Briefly discuss how component classification and weld categorization contributes to a person's ability to extract weld acceptance inspection requirements from the ASME Boiler and Pressure Vessel Code.
3. Briefly discuss when radiography becomes applicable to welds governed by the AWS Structural Welding Code.
4. Briefly discuss or describe the following three conditions which must be met to satisfy the ASME Boiler and Pressure Vessel Code weld acceptance inspections:
   a. Following post weld heat treatment.
   b. Following post weld heat treatment for dissimilar metals.
   c. Prior to the cladding of surfaces.
5. Give examples of welds which are inspected by:
   a. Radiographic testing
   b. Liquid Penetrant testing
   c. Ultrasonic testing
6. Application of Acceptance Standards: Given the following acceptance standards, determine if the weld conditions described by question a through e are acceptable. For any unacceptable conditions, name each condition which makes the weld unacceptable.

Acceptance Standards:

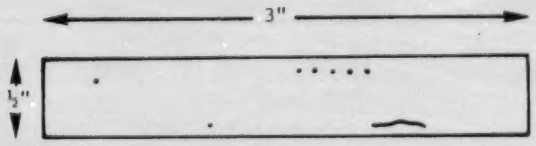
- no cracks.
- no elongated indications exceeding ¼ inch for t up to 3/4 inch, 1/3 t for t from 3/4 inch up to 2 inches, and 3/4 inch for t 2 inches and larger where t equals base material thickness.
- no rounded indications exceed ¼ t or 5/32 inch whichever is smaller where t equals base material thickness.
- no cluster of rounded indications exceeding a cluster length of 1 inch or 2 t whichever is lesser where t equals base material thickness.
- no aligned rounded indications where the sum of individual diameters exceed t in a length of 12 t where t equals base material thickness.
- all arc strikes and spatter removed and blended with surrounding surfaces.
- no undercut exceeding 1/16 inch.
- toe of weld blends smoothly with base metal with radius no smaller than ¼ inch.
- no reinforcement greater than 1/5 t or ¼ inch whichever is less where t equals base material thickness.

a. Visual inspection of a sixteen inch pipe butt joint of ½ inch wall thickness reveals bead rollover along a 1½ inch distance on one side, no discernable cracks or pits, no spatter, no arc strikes, and reinforcement equal to 3/32 inch.

b. Radiographic examination of a 5 inch pressure vessel longitudinal weld reveals two linear indications of 1 inch and 3/4 inch in length, four random rounded indications of 1/8 inch diameter, and one elongated indication of ½ inch length.

c. Radiographic examination of a six inch pipe butt joint of .250 inch wall thickness reveals a series of dark and light elongated indications ranging in size from 1/8 to 11/32 inch, a dark broad indication of ill defined edges along both sides of the weld for its entire length, one linear indication of 1/8 inch, seventeen random rounded indications of 1/16 inch diameter, and one rounded indication of 1/8 inch diameter.

d. Liquid penetrant examination of a tube-to-tubesheet weld of .125 inch thickness reveals the indications illustrated in the following sketch:



Note: All rounded indications equal 1/32 inch

e. Magnetic particle examination of a circumferential butt joint in 3 inch carbon steel shell reveals a cluster of ten rounded indications with cluster size equal to ½ inch by 7/8 inch and no other indications. The ten rounded indications are each 1/8 inch or less in diameter.

MATERIALS

The resource library should possess the following codes to permit accomplishment of the research activity suggested by this module.

- ASME Boiler and Pressure Vessel Code
  - Section III, Division 1 and 2, Nuclear Power Plant Components: General Requirements
  - Section III, Subsection NB, Class 1 Components
  - Section III, Subsection NC, Class 2 Components
  - Section III, Subsection ND, Class 3 Components
  - Section III, Subsection NE, Class MC Components
  - Section III, Subsection NF, Component Supports
  - Section III, Subsection NG, Core Support Structures
  - Section III, Appendices
- AWS Structural Welding Code, D1.1
- AWS Reinforcing Steel Welding Code, D12.1

PROCEDURES

The following is the procedure for carrying out Exercise #1.

Note to Instructor

As previously discussed in the Notes to the Instructor/Student, the student/trainee research of a code applicable to welding to determine specific acceptance inspection requirements for a given weld is suggested as an activity to reinforce the concepts presented by this module. Descriptions of welds and the applicable code for each are given below. It is suggested that each student/trainee be assigned

one weld for which he or she will review the corresponding code in a reference library to determine the specific acceptance inspection requirements and corresponding acceptance standards.

Student/Trainee Procedures

1. For the assigned weld, review the applicable code and extract the weld acceptance inspection requirements and corresponding acceptance standards. Locate the applicable sections, subsections and articles of the code using the guidelines presented by this module. Use the table of contents of the code for the applicable subsection or article to locate applicable paragraphs. Part 2 of this procedure give suggested references for specific weld types.

2. Description of Welds for Research of Acceptance Inspection Requirements and Acceptance Standards
   a. ASME Boiler and Pressure Vessel Code
      (1) Longitudinal weld joint in a class 1 pressure vessel shell of 5 inch thickness.
      (2) Circumferential weld joint in a class 2 pressure vessel shell of 1½ inch thickness.
      (3) Flange to chamber connecting weld joint in a a class 2 pressure vessel of 1½ inch thickness.
      (4) Circumferential butt joint connecting class 2 pressure system piping of ½ inch wall thickness.
      (5) Sidewall joints in a class 3 storage tank of ¼ inch thickness.
      (6) Bottom joints in a class 2 storage tank of 3/8 inch thickness.
      (7) Hardsurfacing of a class 1 component.

(8) Category B partial penetration socket weld in class 2 pipe of .125 inch wall thickness.

(9) Double fillet lap joint in a class 2 component support.

b. AWS Structural Welding Code, D1.1.

(1) Fillet weld of a Tee joint in ½ inch rectangular bar stock.

(2) Double fillet lap joint in 1/8 inch rolled sheet.

c. AWS Reinforcing Steel Welding Code, D12.1

(1) V-groove butt joint in 2 inch diameter bar.

(2) Fillet weld of 1 inch diameter bar to base plate.

DATA TABLE

None.

REFERENCE MATERIALS

The American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III and Section XI, 345 East 47th Street, New York, N.Y. 10017

The American Welding Society, Structural Welding Code, D1.1, 2501 N.W. 7th Street, Miami, Fla. 33125

The American Welding Society, Reinforcing Steel Welding Code, D12.1, 2501 N.W. 7th Street, Miami, Fla. 33125.

1. Matching - Matching the best acceptance inspection method for detecting each defect by placing the symbol of the inspection method adjacent the defect.

Weld Defects

a. _____ slag inclusion in 4" weld.
b. _____ cracks open to weld surface.
c. _____ undercut.
d. _____ underbead cracks in 3" weld.
e. _____ pitting of inside surface of ½ inch tubing.
f. _____ porosity.
g. _____ incomplete fusion in 5" weld.
h. _____ spatter.
i. _____ cracking of ½" tubes installed in a heat exchanger.

Acceptance Inspection Method

VT = Visual inspection
PT = Liquid penetrant examination
MT = Magnetic particle examination
RT = Radiography
UT = Ultrasonic examination
ET - Eddy current examination

Essay - Answer the following questions. Answers should be brief and concise.

2. Describe how each of the following contributes to a person's ability to extract the weld acceptance inspection requirements from the ASME Boiler and Pressure Vessel Code:

a. component classification: _____

_____

_____

b. weld categorization: _____

_____

_____

3. Describe how radiography becomes applicable to welds governed by AWS Structural Welding Code.

_____

_____

_____

_____

_____

_____

_____

_____

4. Describe how sequential processing steps are used in the identification of weld acceptance inspections.

_____

_____

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_____

5. The ASME Boiler and Pressure Vessel Code specifies three conditions which must be met with respect to the point in time where weld acceptance inspections must be applied. Name the three conditions.

_____

_____

_____

_____

_____

_____

_____

_____

6. Completion - Complete the following statements by entering the applicable acceptance inspection requirements of the Boiler and Pressure Vessel Code.

   a. Tube-to-tubesheet welds are inspected by _____ _____.

   b. Welds connecting piping in high pressure systems are inspected by _____.

   c. Pressure vessel fabrication welds are inspected by _____.

   d. Seal welds are inspected by _____

   e. Class 1 welds inspected inservice are examined by _____.

   f. Weld end faces of a pressure vessel nozzle weld preparation of 4.5 inches of base material thickness are inspected by _____.

   g. Weld end faces of carbon steel piping of ½ inch wall thickness in a high pressure system are inspected by _____.